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1 INSPECTION REPORT
NATIONAL DAM SAFETY PROGRAM

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MISSOURI-MUSSELSHELL BASIN
BAIR DAM AND RESERVOIR
MEAGHER COUNTY, MONTANA
MT-6

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MONTANA DEPARTMENT OF NATURAL RESOURCES AND CONSERVATION
(OWNER)

UPPER MUSSELSHELL WATER USERS ASSOCIATION
(OPERATOR)

PREPARED BY:
HOSKINS-WESTERN-SONDEREGGER, INC.

MARCH, 1981

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PHASE 1 INSPECTION REPORT
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EXECUTIVE SUMMARY

Under contract with the Seattle District Corps of Engineers and with representation from the State of Montana Department of Natural Resources and Conservation, the dam owner, and the Upper Musselshell Water Users Association, the dam operator, Bair Dam was inspected by Hoskins-Western-Sonderegger, Inc., on May 7, 1979, under the authority of Public Law 92-367. Bair Dam is located in Meagher County, Montana, approximately 16 miles east of White Sulphur Springs, Montana.

This report was compiled from information obtained during an on-site inspection, an interview with the owners and operators, a review of existing plans, and analysis of hydrologic and hydraulic data. Findings were compared to engineering criteria currently accepted by most private and public agencies engaged in dam design, construction, and operation.

PRINCIPAL FINDINGS AND EVALUATIONS

Bair Dam and Reservoir, owned by the State of Montana Department of Natural Resources and Conservation (DNRC) and operated by the Upper Musselshell Water Users Association, is used for irrigation and recreation. The project consists of a zoned earthfill and rockfill dam and the resulting reservoir. The dam has a concrete chute spillway and gated reinforced concrete outlet conduit. The reservoir has a natural drainage area of 51.1 square miles, a surface area of about 272 acres at normal pool, and total storage at the minimum dam crest elevation (5336.4 feet) of 10,650 acre-feet.

In accordance with the "Recommended Guidelines for Safety Inspection of Dams" (Ref. 1), the 102-foot-high Bair Dam (MT-6) is classified as being of large size and as having a high (Category 1) downstream hazard potential, due to the presence of U.S. Highway 12 and approximately 15 inhabitable structures downstream from the dam, which could be affected by a breach of the dam.

Inspection criteria (Ref. 1) recommend that a large-sized project with a high downstream hazard potential be capable of safely handling a spillway design flood (SDF) equal to the full probable maximum flood (PMF). The PMF is the flood expected from the most severe combination of meteorologic and hydrologic conditions that are reasonably possible in the region.

An estimated PMF was developed for the drainage basin during the dam safety analysis. This PMF, resulting from a 72-hour storm, has an estimated volume of 36,350 acre-feet. The reservoir level at the beginning of the 72-hour storm was assumed to be at the spillway crest elevation, 5325.0 feet. Approximately 3630 acre-feet of storage are available between the spillway crest and the minimum embankment crest elevation. Reservoir routings of the estimated PMF indicate that Bair Dam will handle approximately 17% of the total PMF volume before overtopping if the low-level outlet is fully closed. The project will handle about 19% of the PMF volume before overtopping if the low-level outlet is fully open. The dam will probably erode and fail when overtopped by floodwaters.

In some areas of the upstream face, riprap has been removed by wave action, and moderately erosive embankment material has been exposed. There is some brush along the upstream face at the normal pool elevation. There are trees and brush at scattered locations on the downstream slope. Drains beneath the embankment and beneath the concrete spillway in the left abutment both appear to be operating. However, the concrete floor in the spillway, kept continually wet by water flowing from the drain, shows considerable deterioration. In addition, most horizontal and vertical joints in the spillway show cracking or spalling. Spalling is also occurring along the top of the spillway sidewalls. The foundation drain outlet is covered by several feet of loose rock. Loose rock also partially blocks the conduit outlet. Erosion along the right side of the reservoir, immediately upstream from the right abutment, appears to threaten a highway embankment.

On the basis of the field inspection and the study of hydrologic data, Bair Dam does not have the required discharge and/or storage capacity to safely handle the recommended SDF, and it is not in conformance with inspection guidelines. Because the project cannot handle one-half of the PMF, it is considered unsafe (non-emergency). The observed deficiencies noted in the embankment are also of concern.

PRINCIPAL RECOMMENDATIONS

Due to the availability of storage between the normal pool and the dam crest, the present project provides a degree of flood protection to the downstream area. The intent of report recommendations is to maintain or improve project safety, if feasible, without decreasing its existing flood protection.

A downstream warning plan, for use in the event of possible embankment failure, needs to be developed and placed into operation immediately.

Repair all areas on the upstream face where riprap has been removed by wave action. Remove brush from the upstream and downstream faces of the dam. Remove rocks from the spillway stilling basin. Remove the rocks partially blocking the conduit at its outlet. Uncover the foundation drain outlet. Provide riprap protection for the toe of the highway embankment immediately upstream from the right abutment.

Conduct field investigations, laboratory tests, and engineering studies to determine embankment stability. Make necessary modifications to provide the safety factors called for in the recommended guidelines. In the analysis consider the possibility of earthquakes, shear failure, or the liquefaction of the embankment materials.

Conduct more-detailed hydrologic and hydraulic routing studies to better determine the downstream hazard and required spillway capacity. Modify the project as studies indicate.

Prior to performing the recommended engineering studies and remedial construction, insure compliance with all pertinent laws and regulations.

Stephen H. Nickel
Professional Engineer

PERTINENT DATA

1. GENERAL

Federal Identification No.	MT-6
Owner	Montana Department of Natural Resources and Conservation
Operator	Upper Musselshell Water Users Association
Purpose	Irrigation, recreation
Location	Sec. 35, T10N, R9E Meagher County, Montana
Watershed	North Fork Musselshell River
Downstream Hazard Potential	Category I (High)
U.S.G.S. Quadrangle	Checkerboard, Montana

2. RESERVOIR

Surface Area at Normal Pool (Spillway Crest)	272 acres
Normal Storage (Spillway Crest)	7020 acre-feet
Total Storage (Dam Crest)	10,650 acre-feet
Surcharge Storage	3630 acre-feet
Drainage Area	51.1 square miles
Reservoir Elevation (7 May 1979)	5325.0 feet (NGVD)

3. SPILLWAY

Type	Concrete chute with ogee crest
Crest Elevation	5325.0 feet (NGVD)
Width	60 feet
Spillway Capacity (Dam Crest)	7880 cfs

4. OUTLET WORKS

Type	Reinforced concrete arch-top conduit
Controls	Butterfly valve and emergency slide gate with vertical access tower and manual control from tower
Size	48-inch valves, 4'-6" x 4'-6" conduit
Inlet Invert	5236.5 feet (NGVD)
Outlet Invert	5234.0 feet (NGVD)
Normal Tailwater	5237.0 feet (NGVD)
Discharge Capacity (Dam Crest)	650 cfs

5. DAM

Type	Zoned earth fill and rock fill
Hydraulic Height	102 feet
Crest Length	580 feet
Crest Elevation	5336.4 feet (NGVD)
Crest Width	27 feet
Upstream Slope	1V on 2H upper 12 feet; 1V on 3H below
Downstream Slope	1V on 3H upper 67 feet; 1V on 5H next 20 feet; 1V on 1H below

CHAPTER 1

BACKGROUND

1.1 INTRODUCTION

1.1.1 Authority and Scope

This report summarizes the Phase I inspection and evaluation of Bair Dam, owned by the State of Montana Department of Natural Resources and Conservation (DNRC).

The National Dam Inspection Act, Public Law 92-367 dated 8 August 1972, authorized the Secretary of the Army, through the Corps of Engineers to conduct safety inspections of non-federal dams throughout the United States. Pursuant to that authority, the Office of the Chief of Engineers issued "Recommend Guidelines for Safety Inspection of Dams" (Ref. 1) in May 1975.

The recommended guidelines were prepared with the help of engineers and scientists highly experienced in dam safety from many federal and state agencies, professional engineering organizations and private engineering consulting firms. Consequently, the evaluation criteria presented in the guidelines represent the comprehensive consensus of the engineering community.

The guidelines recommend a two-phased study procedure for investigating and evaluating existing dam conditions so deficiencies and hazardous conditions can be readily identified and corrected. The Phase I study is:

(1) a limited investigation to assess the general safety condition of the dam;
(2) based upon an evaluation of the available data and a visual inspection;
(3) performed to determine if any needed emergency measures and/or if additional studies, investigations and analyses are necessary or warranted; and
(4) not intended to include extensive explorations or analyses or to provide detailed alternative correction recommendations.

The Phase II investigation includes all additional studies necessary to evaluate the safety of the dam. Included in Phase II, as required, should be additional visual inspections, measurements, foundation exploration and testing, material testing, hydraulic and hydrologic analyses and structural stability analyses.

The authority for the Corps of Engineers to participate in the inspection of non-federally owned dams is limited to Phase I investigations with the exception of situations of extreme emergency. In these cases, the Corps may proceed with Phase II studies, but only to the extent needed to answer serious questions relating to dam safety that cannot be answered otherwise. The two phases of investigations outlined above are intended only to evaluate project safety and do not encompass in scope the engineering required to perform design or corrective modification work. Recommendations contained in this report may be for either Phase II safety analyses or detailed design study for corrective work.

The responsibility for implementation of these Phase I recommendations rests with the dam owner and the State of Montana. It should be noted that nothing contained in the National Dam Inspection Act, and neither action nor failure to act under this Act shall be construed: (1) to create liability in the United States or its officers or employees for the recovery of damage caused by such action or failure to act, or (2) to relieve an owner or operator of a dam of the legal duties, obligations, or liabilities incident to the ownership or operation of the dam.

1.1.2 Purpose

The purpose of the inspection and evaluation is to identify conditions that threaten public safety, so that they may be corrected in a timely manner by non-Federal interests.

1.1.3 Inspection

The findings and recommendations in this report were based on a visual inspection of the project, a review of construction drawings, and an interview with representatives of the owner. Logs of soil borings were found, but no stability analysis was available. Inspection procedures and criteria were those established by the Recommended Guidelines for Safety Inspection of Dams (Ref. 1).

Personnel present during the inspection included:

Louis Boitano, Civil Engineer, Seattle Distric Corps of Engineers;
Lawrence Tegg, State of Montana Department of Natural Resources and Conservation;
Robert Clark, State of Montana Department of Natural Resources and Conservation;
Donald Berg, President, Upper Musselshell Water Users Association; and
Howard Dohe, Upper Musselshell Water Users Association.

Hoskins-Western-Sonderegger, Inc. (HWS) personnel who participated in the field inspection and contributed to this report are:

Stephen Nickel, Geotechnical Engineer, Team Leader;
Richard Walker, Hydrologist/Hydraulics Engineer; and
E. L. Hohnstein, Civil Engineer, Dam Section Chief.

This report has been reviewed by representatives of the DNRC and the Upper Musselshell Water Users Association. Their written comments are included in this report.

1.2 DESCRIPTION OF PROJECT

1.2.1 General

Bair Dam is an on-channel irrigation storage impoundment on the North Fork of the Musselshell River. It is operated by the Upper Musselshell Water Users Association. The dam and reservoir are located in Section 35, T10N, R9E in Meagher County, about 14 miles northwest of Martinsdale. The reservoir has a normal surface area of 272 acres with storage at the spillway crest of 7020 acre-feet. The total drainage area is 51.1 square miles. The controlled low-level outlet consists of a 54-inch reinforced concrete arch conduit controlled by a 48-inch butterfly valve. Discharged water enters the North Fork of the Musselshell River. Approximately 8 miles downstream, water is diverted into a canal leading to the South Fork of the Musselshell River, and, approximately 24 miles downstream, water is diverted to the Twodot Canal. A 20-foot wide concrete chute spillway is located in the left abutment. This spillway has a 60-foot wide inlet crest.

Bair Dam is 102 feet high and impounds approximately 10,650 acre-feet at the dam crest elevation. Based on a visual reconnaissance and engineering judgment, approximately 15 homes in the town of Checkerboard and U.S. Highway 12 could be affected by a breach of the dam. On the basis of this information and in accordance with the Recommended Guidelines (Ref. 1), this dam is classified as large in size and has a high (Category I) downstream hazard classification.

1.2.2 Regional Geology

The drainage area of the Musselshell River is a region of basin and range complicated by thrust faulting. Geographically, the Big Snowy Mountains and the Little Belt Mountains are on the north, the Crazy Mountains are on the south, the Castle Mountains are in the middle, and the Big Belt Mountains are on the west, forming a semicircle of mountains around a group of basins extending generally eastward onto the great plains.

Before the late Cretaceous, this was an area of quiet basinal sedimentation. Pre-Cambrian, Paleozoic, and Mesozoic sedimentation produced sandstones and shales. These Pre-Cambrian and Lower and Middle Paleozoic sedimentary and metamorphic rocks are exposed in the mountains and are only exposed due to the mountain-building that occurred here.

During this mountain-building phase, the basinal sediments were formed into a dome containing smaller anticlines and synclines. The most prominent of these are the Little Belt Mountains and the Snowy Mountains. Subsequent to the mountain building came erosion. Erosional debris from the mountains swept down by rivers and streams covered the earlier Cretaceous sandstones and shales and formed the Eocene Fort Union formation, consisting of sandstone, shale, and bituminous coal.

Subsequent erosion of this domed basin has produced the present topography which shows a rim of Fort Union deposits with succeedingly older Cretaceous deposits toward the center of the present smaller basins. These Cretaceous deposits are predominantly the sandstones and shales of the Livingston Formation. The oldest formation exposed in the basins is the Colorado Shale. Later Tertiary gravels and sands form the terraces and benches of the Musselshell River with Pleistocene alluvium along the recent bed of the river.

1.2.3 Seismicity

Bair Dam lies in Seismic Zone 3 as indicated by the Seismic Zone Map (Ref. 1). The seismic probability of Zone 3 is one of a potential for major damage and is based on the known distribution of damaging earthquakes in the region.

No major faults have been mapped in the immediate vicinity of the reservoir, although traces of minor faults can be inferred from aerial photographs and topographic maps. No active faults were found or inferred at the site of the dam. The closest fault identified on the Geologic Map of Montana lies 4 miles north of the dam. This is a large displacement fault but is not known to be active. Other smaller faults lie 12 miles south of the dam.

Epicenters of local earthquakes significant enough to be reported in References 2 and 3 occur approximately along a line from 20 miles northwest of Helena to 25 miles north of Bozeman. The 3 largest reported earthquakes along this line have had intensities of VIII (Modified Mercalli). One of these earthquakes had its epicenter at a point 25 miles north of Bozeman (27 June 1925), while the other two occurred at Helena (18 October and 31 October 1935). Of these 2 epicentral areas, the former is 55 miles and the latter 80 miles from the reservoir. No reported earthquakes have occurred at distances of less than 55 miles from the reservoir.

1.2.4 Site Geology

Bair Dam and most of Bair Reservoir lie in an outcrop area of Precambrian shales and limestones, some of which have been metamorphosed subsequently. Within the first mile upstream from the dam there is an outcrop of a small isolated intrusive body of Tertiary age composed of coarse-grained alkalic rock. At its upper end, the reservoir extends into an area covered by volcanic rocks of Tertiary age, probably andesite and latite.

The dam is located in a narrow gorge cut into the Precambrian rocks. According to the boring logs shown on the plans (see Plate 4), the bottom of the gorge had 5 to 20 feet of cohesive soil on the surface prior to construction of the dam. This was underlain by 0 to 5 feet of gravel which rested on rock. The plans show the embankment cutoff to be keyed into the rock in the abutments and in the foundation (see Plate 4).

1.2.5 Design and Construction History

Records from the DNRC show that the dam was built in 1939 by the State Water Conservation Board of Montana. Construction plans show that the dam embankment is zoned, with a moderately thick upstream impervious section, a

semi-pervious central transition zone, and a thin rock zone on the downstream slope (see Plate 5). A foundation drain was included at the base of the rock zone to collect anticipated seepage. The drain outlet is shown on the plans to be just north of the conduit outlet. The plans indicate that a cutoff was to be constructed beneath the impervious zone. The nature of the cutoff is not known, since the plans indicate that it was to be a concrete cutoff wall, a cutoff trench, or both, as directed. The entire upstream slope was constructed with riprap protection. The riprap was placed on a 12-inch sand and gravel cushion.

CHAPTER 2

INSPECTION AND RECORDS EVALUATION

2.1 HYDRAULICS AND STRUCTURES

2.1.1 Spillway

The uncontrolled, rectangular, concrete chute spillway is located at the east abutment of Bair Dam. This spillway has an ogee-shaped crest section at elevation 5325.0 feet. The crest is 60 feet wide. Downstream of the crest is a 120-foot-long transition section, sloping at 16.5%, in which the width narrows to 20 feet. Downstream of the transition section the chute slopes at 16.5% for another 100 feet and at 33.0% for 125 feet before discharging into a stilling basin. The configuration of the spillway can be seen on Plate 2 and on Photos 5 through 12. Dimensions and elevations of the spillway chute were taken from the construction plans and were field verified.

Spalling of the concrete is occurring along the top of the vertical spillway sidewalls. One section of the sidewall has bowed inward (See Photo 8). Spalling and cracking is also occurring at most of the horizontal and vertical joints, and stains indicating possible seepage are visible at some of these cracks. Spalling and cracking are also visible in the floor of the spillway. At about spillway station 3+23 (See Plate 2), a drainage system discharges into the spillway. Continual discharge from this drain has caused the concrete in the bottom of the spillway to deteriorate near the drain outlet. Loose rocks have fallen into the spillway approach channel just upstream of the crest and also into the stilling basin. Water stains in the stilling basin indicate that spillway flows are passing through the basin without any energy dissipation. However, no significant erosion of the rock outlet channel downstream of the stilling basin was observed.

Due to the accumulation of rock in the approach channel and the low crest height, the spillway discharge rating curve was based on backwater computations rather than on a weir equation. Critical depth was assumed at the crest, and water surface profiles were computed upstream into the reservoir using a Manning's "n" value of 0.040. The capacity of the spillway varies from 0 cfs at the crest elevation of 5325.0 feet to approximately 7880 cfs at the minimum dam crest elevation of 5336.4 feet. The complete discharge rating curve for the spillway is shown on Plate 9.

Water surface profiles were also calculated downstream of the crest to determine the spillway chute capacity. The results show that the spillway chute capacity is exceeded when discharge exceeds approximately 7000 cfs, corresponding to a pool elevation of about 0.5 feet below the dam crest. When the pool is at the dam crest, the spillway chute will overtop roughly between spillway stations 2+00 and 3+00, with the maximum overtopping of about 1 foot occurring near station 2+20. Depending on whether this water stays in the channel above the chute, the chute could also overtop from about station 3+30 to station 3+80, with a maximum overtopping of about 6 inches at station 3+38. Spillway chute overtopping could cause embankment erosion and possible dam failure.

2.1.2 Outlet

The low-level outlet through the dam is a cast-in-place, reinforced concrete conduit having a composite section, 54 inches wide. The conduit has 27-inch-high vertical sidewalls and a 54-inch-diameter, semi-circular top. The conduit has a cast iron liner downstream of the control tower, although this liner is not shown on the plans. Outlet discharges are controlled by a 48-inch-diameter butterfly valve. There is also a 48-inch-diameter emergency slide gate. The butterfly valve is operated manually from the dam crest, and the emergency gate is operated manually from a platform inside the control tower approximately 90 feet below the dam crest elevation. The configuration of the outlet works can be seen on Plate 3 and on Photo 13.

Inspection of the outlet conduit was made possible by closing the emergency gate and opening the butterfly valve. No problems were noted in the operation of the controls. Cavitation damage was found above the butterfly valve, on and near the top deflector. DNRC inspection reports indicate that repair of cavitation damage has been necessary in this area in the past. Possible cavitation damage was also found on the conduit wall on the outside of the bend in the conduit, about 140 feet downstream from the control chamber. Although there is no energy dissipator at the conduit outlet, no evidence of erosion was found in the rock outlet channel. The conduit coutlet is partially blocked by rocks in the outlet channel. The conduit upstream of the control chamber could not be inspected.

The conduit outlet is 102.4 feet below the minimum crest elevation of the dam and 91.0 feet below the spillway crest elevation. The discharge capacity of the outlet was based on full pipe flow conditions. With the 48-inch butterfly valve completely open, the discharge capacity of the outlet was calculated to be 610 cfs with the pool at the spillway crest and 650 cfs with the pool at the minimum crest of the dam. The discharge rating curve for the outlet is shown on Plate 8.

2.1.3 Freeboard

The effective fetch for wind-generated waves is estimated to be about one-half mile, and the wave run-up and set-up on the embankment is approximately 3.25 feet (Ref. 4). An approximate 11.4-foot difference exists between the minimum crest elevation of 5336.4 feet and the normal pool elevation of 5325.0 feet. This freeboard is considered adequate in preventing wave overtopping when the pool is at the normal operating level. Routings indicate that dam overtopping occurs during the PMF; therefore, no freeboard exists during the recommended spillway design flood. At the time of inspection, the lake was at the normal pool operating level.

2.2 HYDROLOGY, CLIMATOLOGY AND PHYSIOGRAPHY

2.2.1 Physiography and Climatology

The climate of the area around Bair Reservoir is highly variable, having great temperature extremes, and is most generally characterized as continental. The effects of foehn or chinook winds, which are westerly or southwesterly and

Pacific Maritime in origin, are important in determining the extreme precipitation and runoff conditions which occur in this area. The summers are warm with cool nights and low humidity while winters are cold and highly variable in severity.

White Sulphur Springs, in Meagher County, is the nearest climatological station and is located 16 miles west in the Smith River Valley at 5100 feet elevation. Precipitation and climatological data for this station are available for approximately 90 and 70 years, respectively. The mean annual precipitation at White Sulphur Springs is about 18 inches. Temperature extremes at White Sulphur Springs range from about -50° F to 105° F (Ref. 5). The average last freeze date is June 19th and the average first freeze date is August 28th (Ref. 6).

The drainage basin, which extends north of the reservoir, is pear-shaped and encompasses an area of approximately 51.1 square miles. Basin elevations range from the normal pool elevation of 5325.0 feet to approximately 8082 feet at the extreme northern part of the basin. The Crazy Mountains and Little Belt Mountains lie southeast and north of the reservoir, respectively.

2.2.2 Reservoir Storage and Spillway Discharge

The reservoir has a surface area of about 272 acres and a storage of 7020 acre-feet at the spillway crest elevation of 5325.0 feet. Approximately 3630 acre-feet of storage are available between this spillway crest and the minimum crest elevation of the dam. The discharge of the spillway at the minimum crest of the dam is 7880 cfs. This discharge would increase an additional 650 cfs if the control valve for the low-level outlet were fully opened.

2.2.3 Estimated Probable Maximum Flood

The probable maximum flood (PMF) is defined as the flood expected from the most severe combination of critical meteorologic and hydrologic conditions that are reasonably possible in the region. A storm, the intensity of which approached probable maximum precipitation (PMP) intensity, did occur in Montana in June 1964.

A PMP storm of 72-hour duration was applied to the basin. The 24-hour, 6-hour and 1-hour PMP depths were estimated from the National Weather Service Technical Paper 38 (Ref. 7) to be 15.3 inches, 11.7 inches and 6.4 inches, respectively. The 48-hour and 72-hour depths were then calculated as 110 percent and 115 percent of the 24-hour index PMP, respectively. All 6-hour increments from 0 to 72 hours and the hourly increments of the maximum 6-hour increments were arranged in a critical order of occurrence, using criteria in U.S. Weather Bureau Hydrometeorological Report No. 43 (Ref. 8).

The PMF was assumed to result from a PMP storm in the late spring over unfrozen ground. The prevalent soil types in the Bair Reservoir basin as determined from Reference 9 are approximately 10 percent Hydrologic Soil Group (HSG) B and 90 percent HSG C. The recommended constant minimum soil loss rates of 0.15 in/hr and 0.08 in/hr were used for HSG's B and C, respectively

(Ref. 10). The assumed constant soil loss rate for the basin was calculated as being 0.087 in/hr, this being the weighted average of the loss rates for the two soil groups. No inital loss was subtracted at the beginning of the PMP storm. Direct precipitation onto the surface of the lake was added in with no losses.

2.2.4 Flood Routing

The reservoir level at the beginning of the 72-hour PMP storm was assumed to be at the spillway crest elevation of 5325.0 feet, which corresponds to the normal pool condition. The total volume of the 72-hour PMF for Bair Reservoir is approximately 36,350 acre-feet with a peak flow rate of approximately 125,400 cfs. Routings indicate that the reservoir will handle, through storage and spillway discharge, approximately 17% of the PMF volume before overtopping if the outlet control gates are closed and approximately 19% of the PMF volume if the outlet control gates are open.

The PMF inflow hydrograph was developed using the SCS dimensionless unit hydrograph. Hydrographs were generated and combined using the HEC-1 (Dam Safety Version) computer program (Ref. 11). Reservoir routings of the PMF were made using the modified Puls method, which is also contained in the HEC-1 program.

2.3 GEOTECHNICAL EVALUATION

2.3.1 Dam Embankment

The 102-foot-high dam has a crest width of 27 feet and a crest length of about 580 feet. The upstream slope is 1(V):2(H) for the upper 12 feet and 1(V):3(H) below. The downstream slope is 1(V):3(H) for the upper 67 feet, 1(V):5(H) for the next 20 feet, and 1(V):1(H) for the remainder.

The crest elevation is 5337.0 feet at the right abutment (station 0+00) and drops to the minimum of 5336.4 feet at station 0+50. From that point the crest elevation generally rises to 5338.3 feet at station 3+00 and then generally falls to 5337.0 feet at station 5+00. The elevation along the embankment centerline continues to fall to elevation 5335.0 feet at the edge of the right wall of the spillway at station 5+22; however, this low spot is downstream from and protected by the right spillway inlet wingwall, with a top elevation of 5337.0 feet, which begins at approximately station 4+90.

The embankment is zoned and appears to contain a sandy silty clay to sandy clayey silt in an upstream impervious zone. The design plans show a more pervious material of unknown characteristics in the central zone and gravel and rock in the downstream zone. The zoning plan is shown on Plate 5. The source of the borrow is not known. The exposed material appears to be erosive, and it is estimated that the dam will fail rapidly upon overtopping. The upstream embankment face is protected with riprap; however, riprap has eroded away in several areas. In addition, the 12-inch granular filter or bedding course, shown on the plans as being beneath the riprap, could not be found, and embankment material was being carried out through the riprap by wave action. Trees and brush were noted growing at scattered locations on the dam embankment (See Photos 3 and 4).

2.3.2 Foundation Conditions, Seepage, and Drainage

Boring logs shown on the plans (See Plate 4) show that the embankment foundation is composed of an upper cohesive layer of clay loam and broken shale, 5 feet to 20 feet thick, above 0 to 5 feet of loose sand and gravel. These Tertiary or Quaternary deposits are indicated as being directly above hard metamorphic rock and laminated and broken, brown metamorphic rock, underlain by solid rock. The plans called for excavation to "firm and semi-impervious material" under the upstream impervious zone, with a "concrete cutoff wall, cutoff groove, or both" extending to bedrock.

There was no evidence of seepage that was not being collected by the foundation drain system.

The foundation drain outlet could not be observed, because the area had been covered by several feet of loose rock. Although water was flowing into the outlet channel, it was impossible to determine the quantity of water flowing and whether the drain was operating at or below its capacity.

The plans show a drainage system beneath the concrete spillway, with an outlet near spillway station 3+23 (See Plate 2). The continual discharge from this drain has caused the concrete in the bottom of the spillway channel to deteriorate in the vicinity of the drain outlet.

The plans show a mine tunnel entrance approximately 500 feet upstream of the left abutment at an elevation of about 5260 feet. The direction and extent of the tunnel are not shown. Since the tunnel is in rock and there are no concentrated seeps from the rock in the immediate vicinity of the embankment, the tunnel is not considered a threat to the stability of the dam.

2.3.3 Stability

No evidence of slope instability was noted during the inspection. The guidelines require a minimum safety factor of 1.50 for the condition of steady seepage. In our experience safe downstream slopes on other dams of similar materials and dimensions are generally from about 1(V):2.5(H) to 1(V):3(H). By this estimate the downstream slope may be stable. However, because of the downstream hazard involved, an evaluation of the stability of the embankment is necessary to determine whether adequate safety factors are, in fact, provided by the embankment design.

2.4 PROJECT OPERATION AND MAINTENANCE

2.4.1 Dam

Regular inspections are performed by employees of the DNRC, with suggested maintenance practices generally carried out. Copies of previous inspection reports are on file with the DNRC. From previous reports, it appears that inspections and maintenance work concentrate on the appurtenances, at the expense of the embankment. Examples of this are the areas of erosion in the riprap, the rock covering the foundation drain outlet and partially blocking the conduit outlet, and the rock which has accumulated in the stilling basin of the spillway.

2.4.2 Reservoir

The level of Bair Reservoir fluctuates seasonally, being low in winter, full by the start of the irrigation season and low again by autumn. Water is obtained from runoff into the North Fork of the Musselshell River. The dam has a controlled low-level outlet which releases water for downstream diversion into Martinsdale Reservoir or into the Twodot Canal.

There is some rock debris that is partially filling the spillway approach channel. This debris has resulted from spalling of the rock surface in a semi-circular area upstream from the left abutment (See Photo 5). This area may have been created during construction of the dam or may be the result of an old slope failure. The material at the base of the slope appears to be too fine and of insufficient quantity to be the direct result of a recent slope failure. No remedial action appears necessary; however, this area should be monitored during annual inspections. There is also some erosion on the shore of the reservoir below the highway embankment upstream from the right abutment. This erosion appears to be threatening the highway embankment.

2.4.3 Warning System

There is no formal warning system or plan of action to warn persons downstream in the event of impending dam failure.

CHAPTER 3

FINDINGS AND RECOMMENDATIONS

3.1 FINDINGS

Visual inspection of Bair Reservoir and Dam, supplemented by analysis of the project in terms of the recommended guidelines' performance standards, resulted in the findings summarized in Sections 3.1.1 through 3.1.4.

3.1.1 Size, Hazard Classification, and Safety Evaluation

In accordance with inspection guidelines, Bair Dam is classified as large in size, and, based on our visual inspection and judgment, it has a high downstream hazard potential. The guidelines' recommended spillway design flood (SDF) for this project is, therefore, 100 percent of the PMF. Based on reconnaissance level investigations, the project is incapable of handling 50 percent of the PMF volume without overtopping and causing the dam to fail, which, in our judgment, could seriously jeopardize life and property downstream. Under inspection criteria, Bair Dam is considered unsafe (non-emergency) until the recommended actions are completed.

3.1.2 Embankment Dam

The embankment appears to be in generally good condition from a structural standpoint. The only problems found at the time of the inspection were in the area of maintenance. Wave action has removed or partially removed riprap in several areas on the upstream face. In addition, the granular bedding material for the riprap does not appear to be able to act as a filter, allowing the embankment material to move out through the riprap. This was observed in a choking of the riprap with embankment fines. There are small areas of trees and brush near the normal pool elevation on the upstream slope and some scattered trees and brush on the downstream slope. The foundation drain outlet is covered by loose rock. Embankment stability could not be determined with available data. A stability analysis of the embankment should be performed and placed on file.

3.1.3 Spillway and Outlet Works

Spalling is occurring along the top of the sidewalls of the concrete chute spillway. Spalling and cracking is also occurring at most of the horizontal and vertical joints in the walls and floor of the chute. Evidence of possible seepage was found at some of these cracks. Discharge from a drainage system has caused deterioration of the spillway floor near the drain outlet. Loose, spalled rocks have fallen into the spillway approach channel and the stilling basin.

No problems were noted in operation of either the 48-inch emergency gate or the 48-inch butterfly valve. Cavitation damage was found above the butterfly valve, on and near the top deflector. Possible cavitation damage was also found on the outlet conduit wall on the outside of the bend in the conduit,

about 140 feet downstream from the control chamber. The conduit outlet is partially blocked by rocks in the outlet channel.

3.1.4 Spillway and Reservoir Capacity

The spillway discharge capacity and the reservoir storage capacity are insufficient to prevent overtopping of the dam during the estimated PMF. The spillway and reservoir can handle only approximately 17% of the PMF volume with the control gates closed and only approximately 19% of the PMF volume with the control gates open. Hydraulic calculations also indicate that the spillway chute capacity will be exceeded prior to dam overtopping. Spillway chute overtopping could lead to dam failure under less than PMF conditions.

3.1.5 Operation and Maintenance

Operation and maintenance are performed by the Upper Musselshell Water Users Association. The site is visited by representatives of the operators approximately daily during the irrigation season and approximately once every 2 to 4 weeks for the remainder of the year. Water from the North Fork of the Musselshell River is stored to be released from the low-level outlet as needed for irrigation downstream. As a consequence the reservoir level can fluctuate seasonally. Although some maintenance appears to be performed, more diligence is required. Neither the maintenance of the dam nor the appurtenances appears to be adequate, allowing the general condition of the structure to decline.

There is no formal warning system or plan of action to alert downstream inhabitants in the event that dam failure is imminent.

3.2 RECOMMENDATIONS

1. Immediately develop, implement and test an emergency warning plan for use in the event of a potential for overtopping or failure by other means.

2. Locate and expose the foundation drain outlet. Perform any excavation necessary to permit free flow from the outlet. This will facilitate monitoring of drain flow both for quantity of flow and for evidence of internal erosion or piping. Provide the outlet with a suitable animal guard. Remove the rocks partially blocking the conduit outlet. Remove rocks from the spillway stilling basin. Inspect conduit upstream from the 48-inch-diameter slide gate.

3. Repair all areas on the upstream face where the embankment is exposed. Use a properly designed filter blanket under all new riprap.

4. Remove brush from the upstream and downstream faces of the dam. Backfill root holes with proper materials and compact.

5. Provide riprap protection for the toe of the highway embankment along the right side of the reservoir, immediately upstream from the right abutment. Provide erosion protection for the dam embankment in the event of spillway chute overtopping.

6. Repair cavitation damage on and near the top deflector of the butterfly valve and on the outside of the bend in the outlet conduit. Repair all spalled concrete on the floor and on top of the walls of the spillway chute.

The above recommendations will not make the dam safe, but will reduce risk to life and property while the following recommended actions are being taken.

7. Conduct engineering studies to better determine the downstream hazard and recommended spillway design flood and to determine the stability of the dam embankment. The studies involved in the stability analysis are to be performed by an experienced dam engineer and should include:

   - Sampling and testing of the soils in the dam and foundation;
   - Installation, maintenance, and evaluation of piezometers in the dam and the abutments and along the downstream toe;
   - Performance of stability analysis using actual strength and piezometric conditions;
   - Determination of seismic stability, including the potential for liquefaction, by appropriate methods; and
   - Evaluation of the gradation and thickness of the upstream riprap to see if a greater thickness and/or a different gradation of bedding material is required.

8. Consistent with the results of the engineering studies, modify the project as studies indicate.

9. Continue all existing programs for periodic inspections, at intervals not to exceed 5 years. However, include in the inspection team a geotechnical engineer knowledgeable in the design and construction of embankment dams.

10. Intensify regular maintenance efforts to prevent deterioration of the embankment and its appurtenances.

Prior to performing the recommended engineering studies and remedial construction, insure compliance with all pertinent laws and regulations.

REFERENCES

1. U. S. Army Corps of Engineers, Office of the Chief of Engineers, Report to the U. S. Congress, National Program of Inspection of Dams, Vol. 1, Appendix C, "Recommended Guidelines for Safety Inspections of Dams," Washington, D.C., Department of the Army, May 1975.

2. U. S. Department of Commerce, Earthquake History of the United States, Publication 41-1, Washington, D.C.

3. U. S. Geological Survey, "Earthquake Information Bulletin" Washington, D.C., 1973-1978.

4. U. S. Army Corps of Engineers, Office of the Chief of Engineers, "Wave Run-up and Wind Set-up on Reservoir Embankments," Engineer Technical Letter No. 1110-2-221.

5. Nunns, F. K., Soil Survey of the Upper Musselshell Valley Area, Montana, Montana Agricultural Experiment Station, U. S. Department of Agriculture, Series 1939, No. 1, November 1943.

6. Caprio, J. M., "Montana: Average Dates of Freeze," Folders No. 81, 82, and 83, Montana Agricultural Experiment Station, Montana State College, Bozeman, Montana, March 1965.

7. U. S. Department of Commerce, Weather Bureau, Generalized Estimates of Probable Maximum Precipitation for the United States West of the 105th Meridian, Technical Paper No. 38, U. S. Government Printing Office, Washington, D.C., 1960.

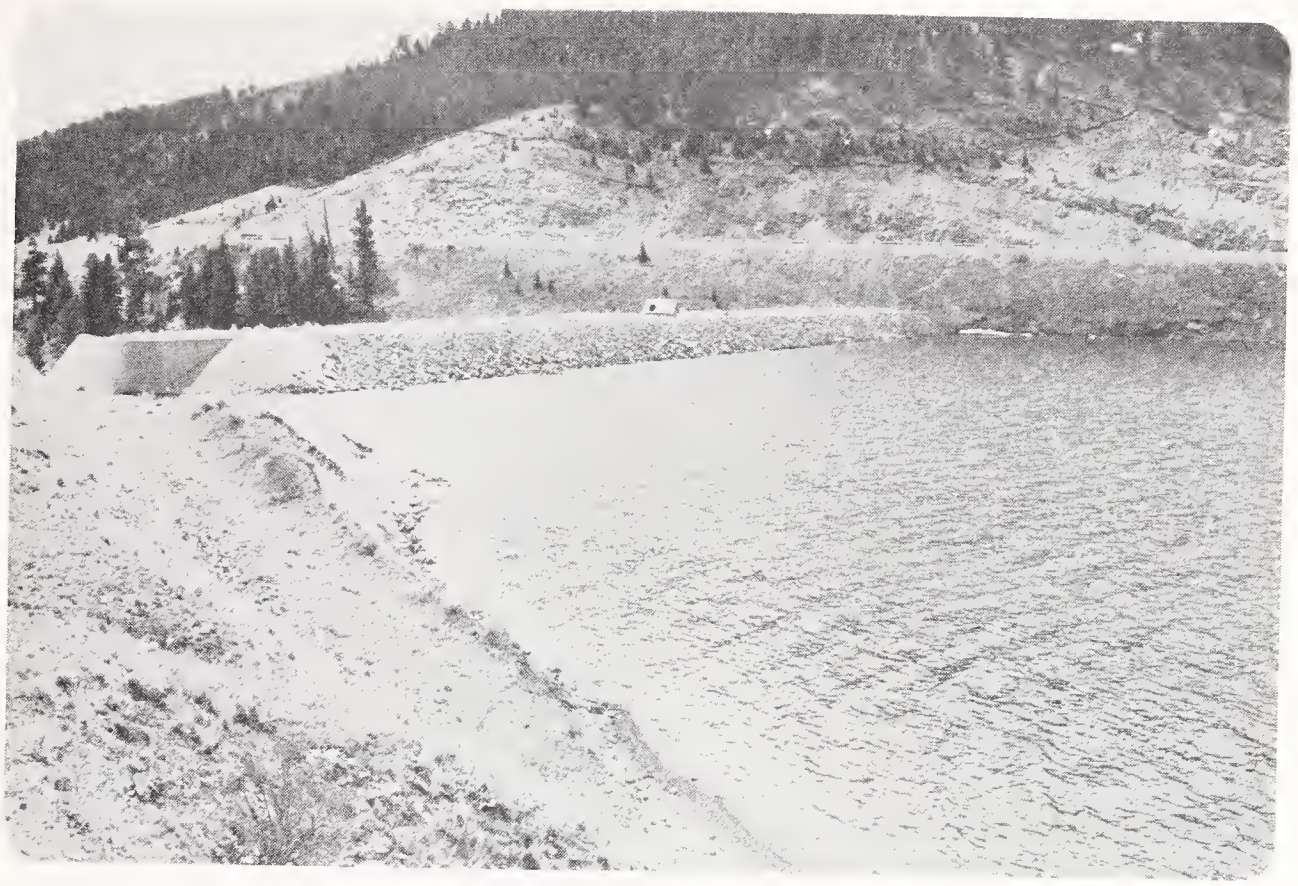
8. U. S. Department of Commerce, Environmental Science Services Administration, Weather Bureau, Probable Maximum Precipitation, Northwest States, Hydrometeorological Report No. 43, Washington, D.C., November 1966.

9. Southard, A.R., Soils in Montana, Bulletin 621, Montana Agricultural Experiment Station Station, Montana State University, Bozeman, Montana, Reprint July 1, 1973.

10. U. S. Army Corps of Engineers, Hydrologic Engineering Center, "Unit Hydrograph Concepts and Calculations," unpublished notes distributed at North Pacific Division Workshop on Phase I Dam Safety Investigations, held Seattle, Washington, November 1978.

11. U. S. Army Corps of Engineers, Hydrologic Engineering Center, Flood Hydrograph Package (HEC-1), Users' Manual for Dam Safety Investigations, Davis, California, September 1978.

(Photo 1) Overview, Bair Dam and Reservoir.



(PHOTO 2) Spillway Inlet and Upstream Face From Left Abutment.

(PHOTO 3) Crest of Dam From Right Abutment.

(PHOTO 4) Spillway Inlet and Downstream Face From Left Abutment.

(PHOTO 5) Spillway.

(PHOTO 6) Looking Upstream Into Spillway Inlet.

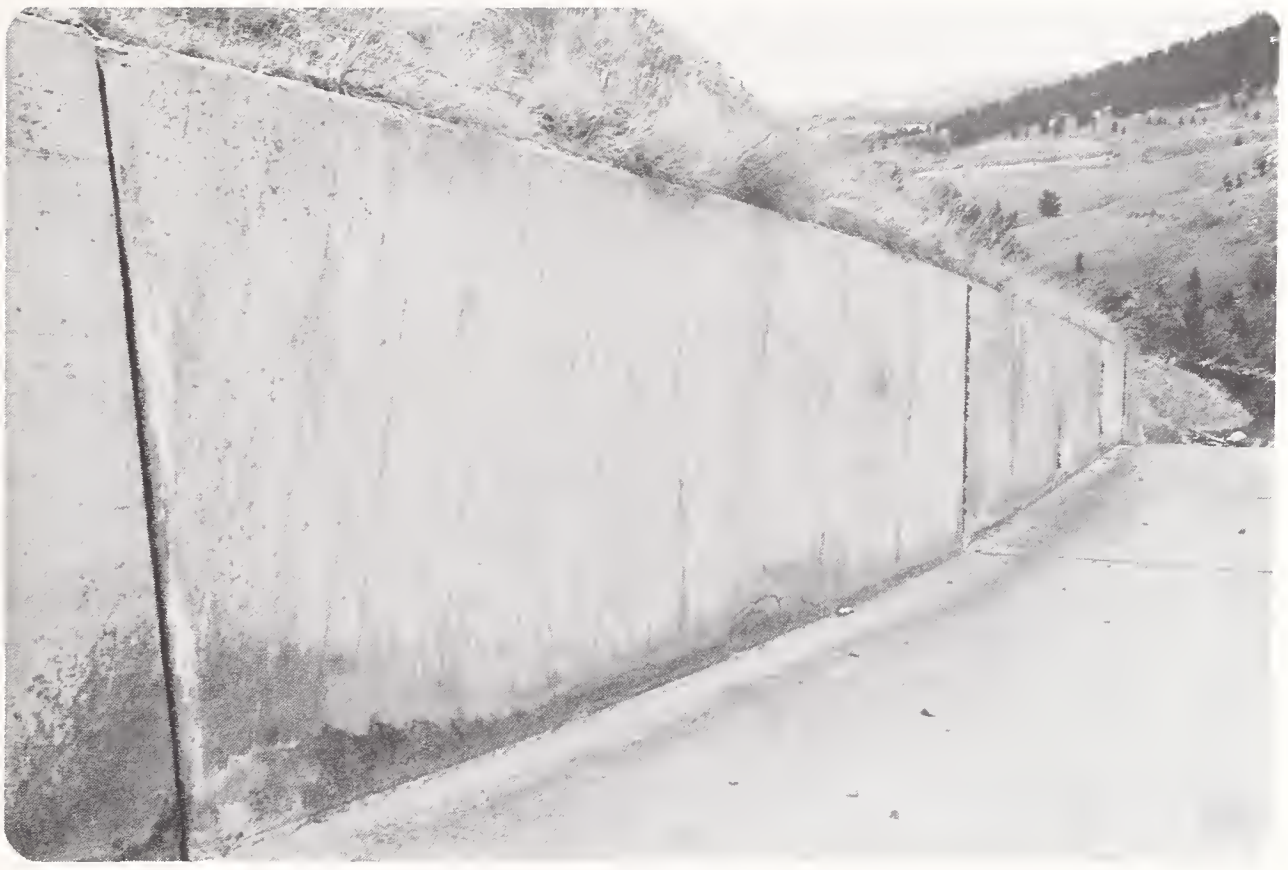
(PHOTO 7) Looking Upstream in Spillway From Just Below Break in Slope. Note: Water Flowing From Drain Outlets and Deteriorated Condition of Concrete.

(PHOTO 8) Right Wall of Spillway Near Stilling Basin. Note: Spalled Concrete on Top of Wall and Old Repaired Areas. Also Note That Wall Bows Inward.

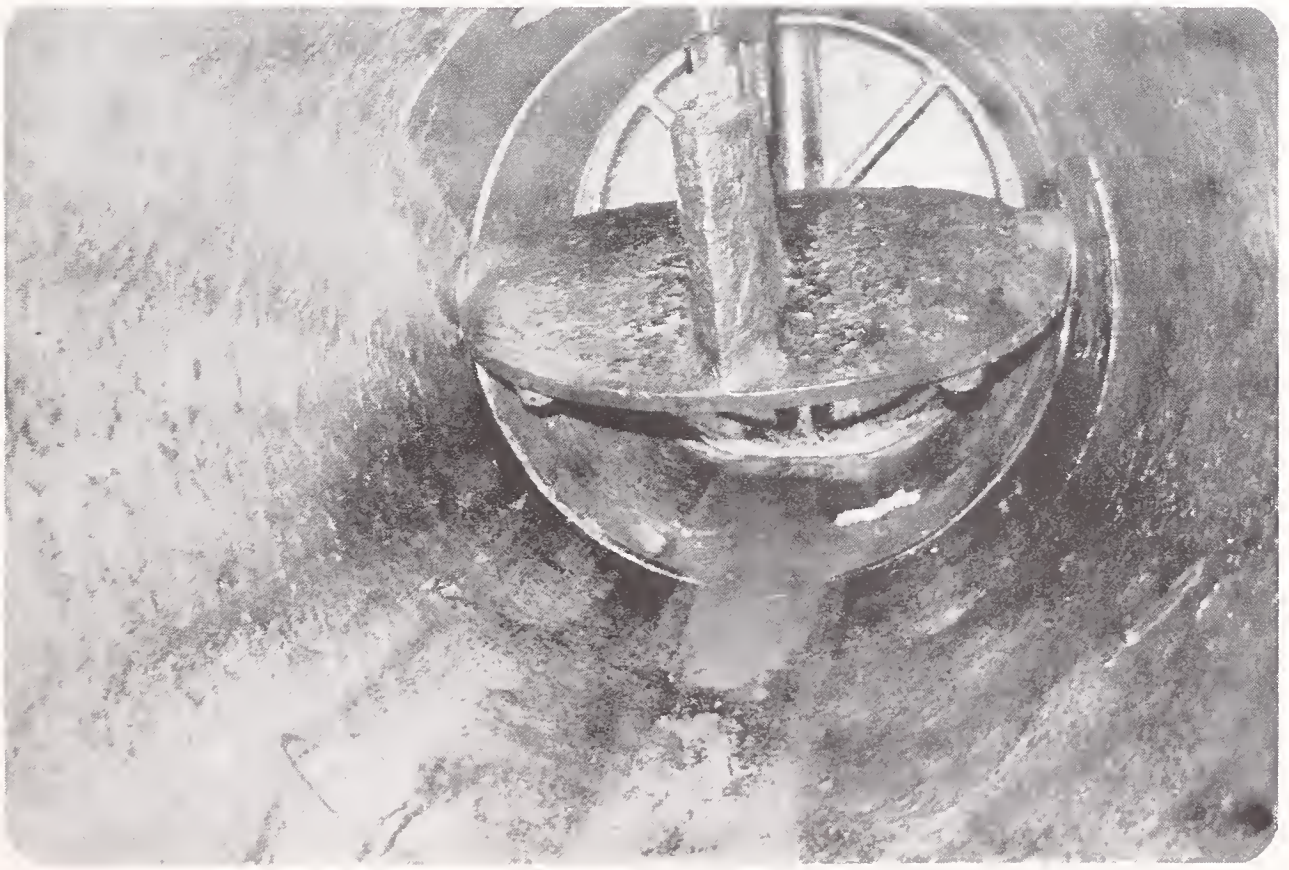
(PHOTO 9) Looking Downstream in Spillway From Just Above Drain Outlets. Note: Rock Rubble in Stilling Basin.

(PHOTO 10) Spillway Stilling Basin.

(PHOTO 11) Second Joint Below Inlet, Left Side of Spillway. Repaired Floor Joint, Deteriorated Wall Joint.



(PHOTO 12) Left Side of Spillway Above Break in Slope.



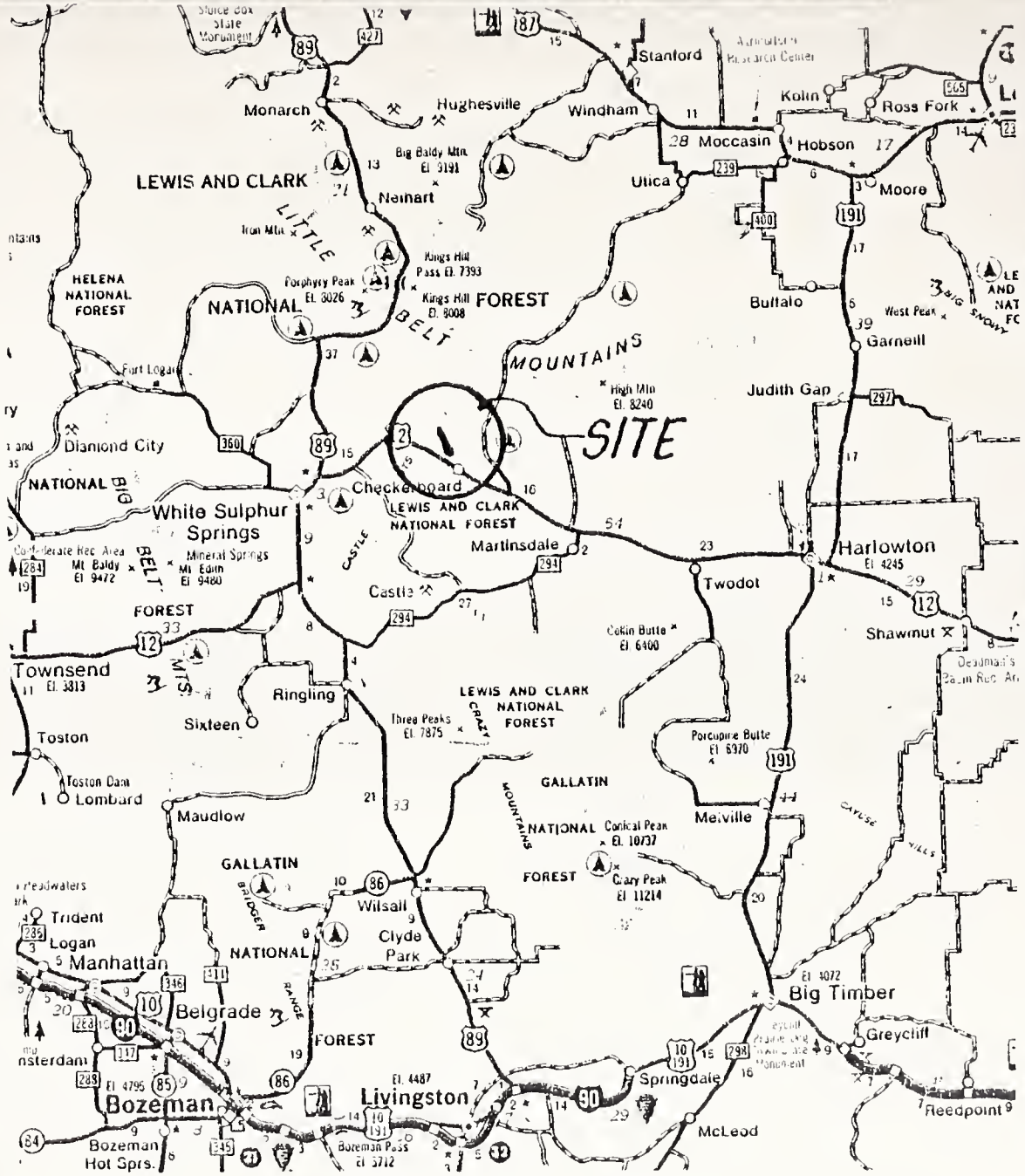
(PHOTO 13) In Outlet Conduit. Butterfly Valve Opened, Slide Gate Closed.

(PHOTO 14) Conduit Outlet.

(PHOTO 15) Seep Area, Probably Foundation Drain Outlet, Left of Conduit Outlet.

(PHOTO 16) Looking Downstream From the Crest of the Dam.

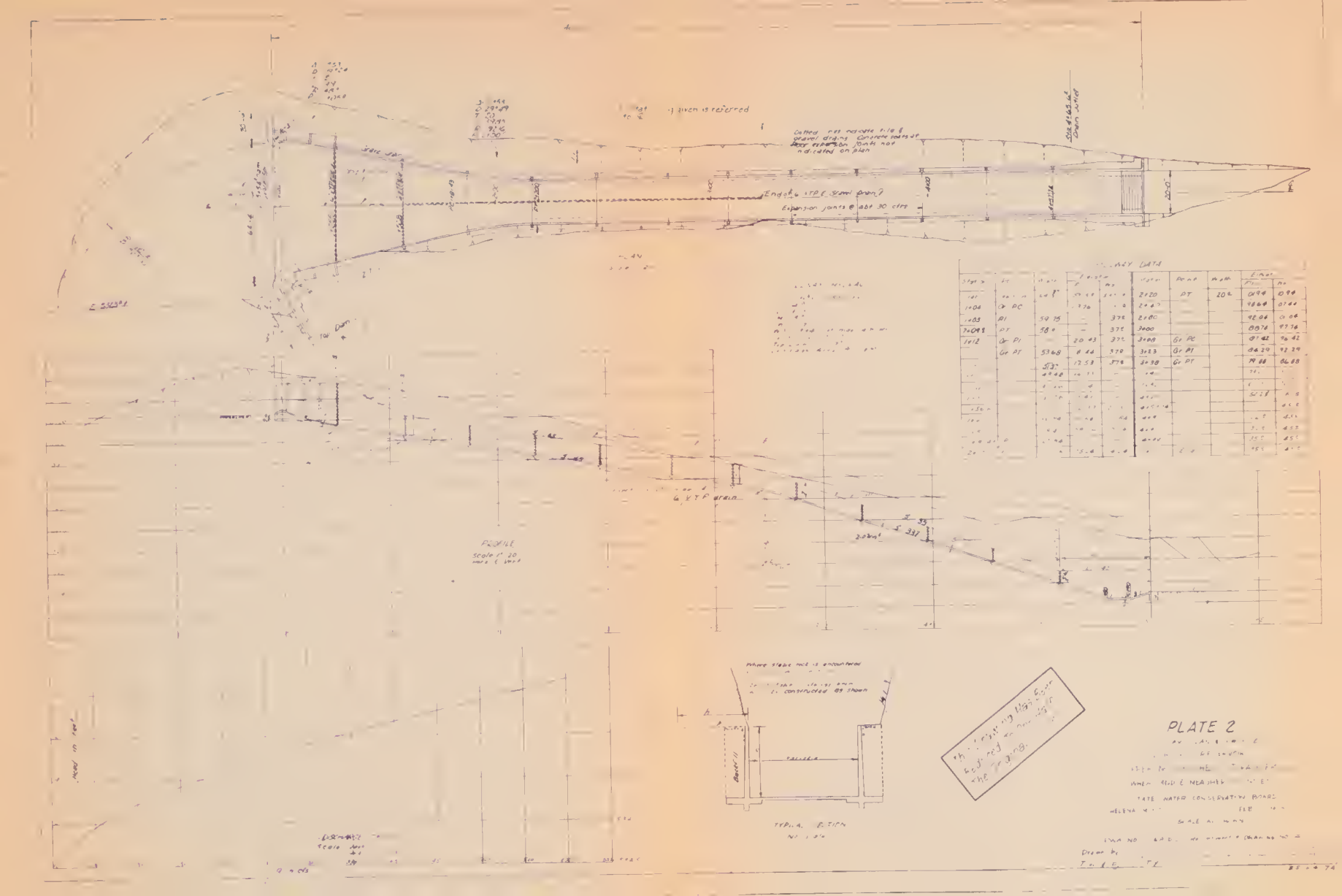
SITE PLAN

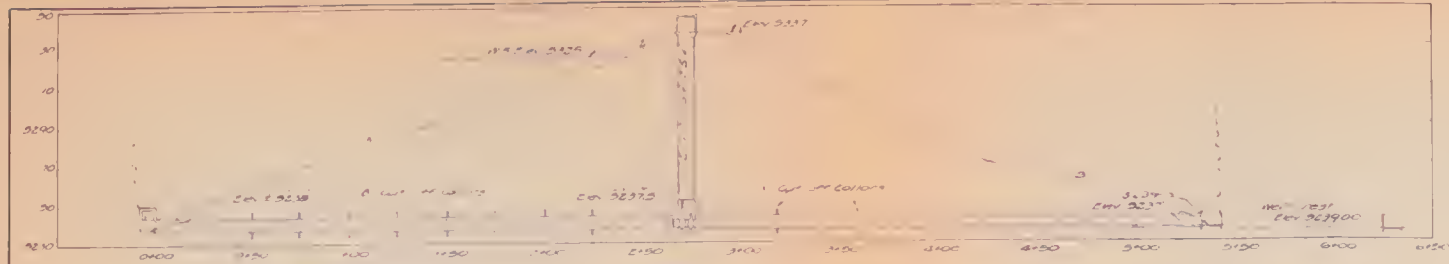


VICINITY MAP

N

PLATE 1
BAIR DAM & RESERVOIR
SITE PLAN & VICINITY MAP

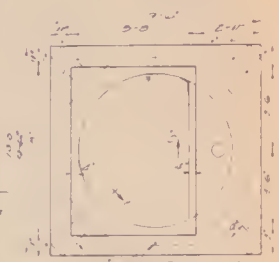

Engelm. STPE Steel piers?
Expansion joints @ abt 30 ctrs
PROFILE
scale 1" = 20 ft
TYPICAL SECTION
PLATE 2



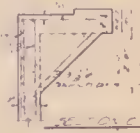
PROFILE
Scale 1"=40'

SECTION B-B
Scale 3/8" = 1'-0"

TOWER HOOD BARS

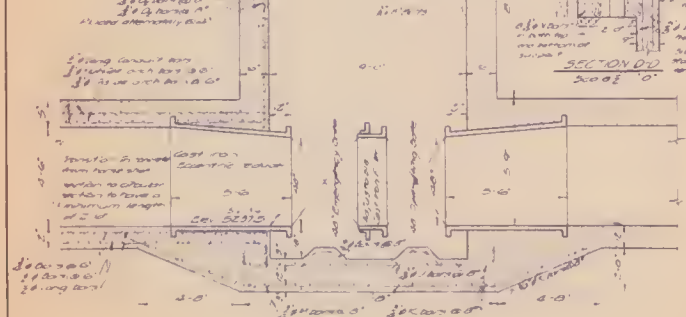


PLAN OF TOWER
Scale 3/8" = 1'-0"

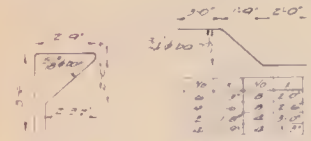


SECTION C-C
Scale 3/4" = 1'-0"

SECTION D-D
Scale 3/4" = 1'-0"

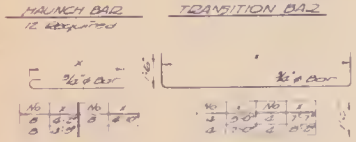


SECTIONAL ELEVATION
Scale 3/8" = 1'-0"



HAUNCH BAR
12 Required

TRANSITION BAR

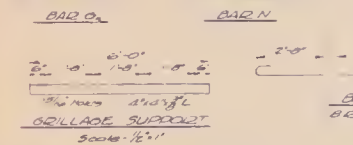


BAR O_2

BAR N

BAR K
4 Required

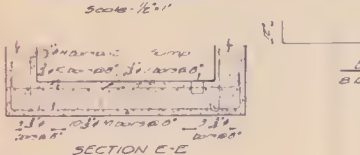
BAR K
34 Required



GRILLAGE SUPPORT
Scale 1½"=1'

BAR H
8 Required

BAR H
34 Required

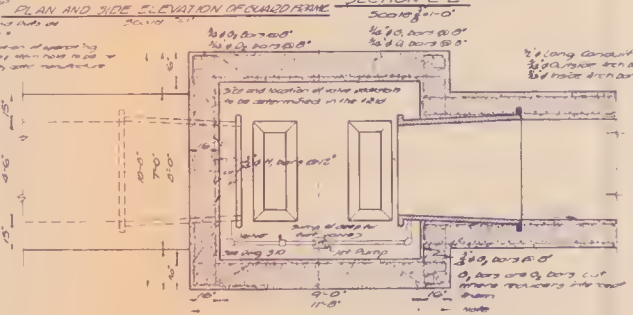


BAR E
8 Required

BAR J
22 Required

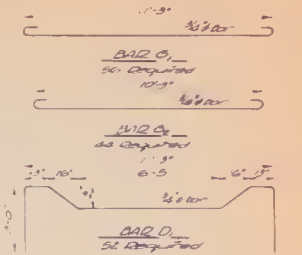
PLAN AND SIDE ELEVATION OF GUARD FRAME

SECTION E-E
Scale 1½"=1'-0"



SECTION A-A
Scale 3/8"=1'-0"

THIS DRAWING HAS BEEN REDUCED TO ONE HALF THE ORIGINAL SCALE



BAR G_1
56 Required

BAR G_2
48 Required

BAR D
52 Required

BAR O_2
30 Required

BAR M
10 Required

GENERAL NOTES

Exposed concrete edges to be chamfered 1½".

Lettering to be placed a minimum distance of 2½" from the surface of the concrete unless otherwise shown.

All bars with hooks to have hooks formed with a diameter of at least 6 diameters of the bar.

Ladder and guard frame to be placed as close to gate stem as a pending stem will permit as shown in PLAN OF TOWER.

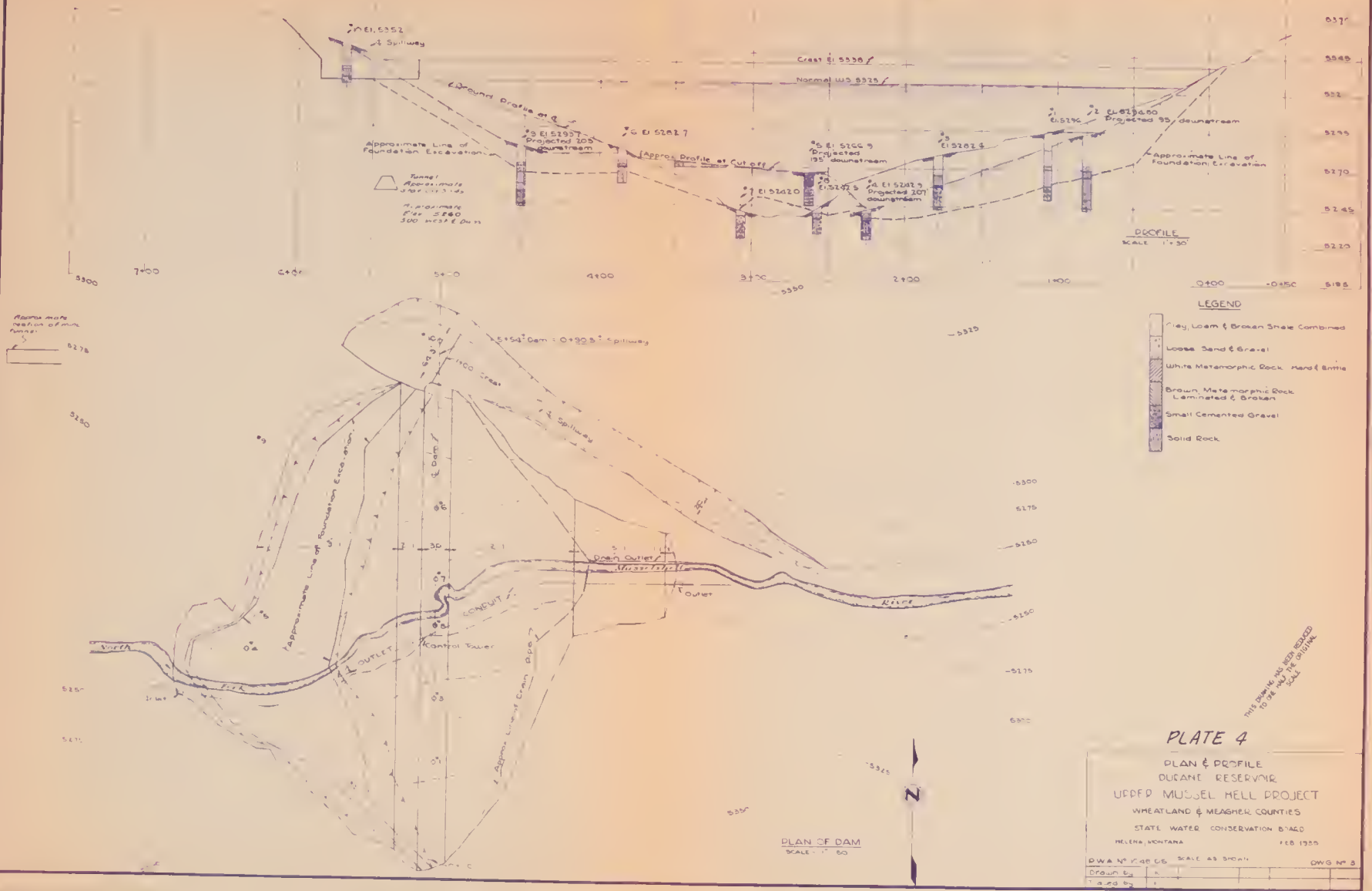
Ingetts to be of a standard type and approved by the Engineer.

See Dwg No 7 for ladder & grillage details

PLATE 3

CONTROL CHAMBER & TOWER OF CONTROL WORKS
DURAND RESERVOIR
UPPER MUSSELSHELL STORAGE PROJECT
MEAGHER AND WHEATLAND COUNTIES
STATE WATER CONSERVATION BOARD
HELENA, MONT. Jan 29 1938
Scale as shown
DWA No. 10008 09 Dwg No 9

Drawn by W.V.J	Traced by NOB	Checked by
Revised by	Revised by	Revised by NOB


El. 5352
Spillway
Crest El 5330
Normal WS 5325
Ground Profile at ℄
El 5293.7
El 5282.7
Approx. Profile at Cut off
El 5276
El 5293.80
Projected 95' downstream
El 5282.4
El 5276.9
Projected 195' downstream
El 5282.9
Projected 207' downstream
El 5242.0
El 5242.5
Approximate Line of Foundation Excavation
Approximate Line of Foundation Excavation
Tunnel
Approximate
Size 11'-3" dia
Approximate
Elev 5260
300 West ℄ Dam
PROFILE
SCALE 1"=30'
LEGEND
Clay, Loam & Broken Shale Combined
Loose Sand & Gravel
White Metamorphic Rock Hard & Brittle
Brown Metamorphic Rock Laminated & Broken
Small Cemented Gravel
Solid Rock
Approximate location of mine tunnel
5+54 Dam : 0+98.5 Spillway
Spillway
Dam
Drain Outlet
Outlet
Conduit
Control Valve
Outlet
Approximate Line of Foundation Excavation
Approx. Line of Drain Pipe
North
Fork
River
PLAN OF DAM
SCALE 1" = 80'
N
THIS DRAWING HAS BEEN REDUCED TO 3/4 THE ORIGINAL SCALE
PLATE 4
PLAN & PROFILE
DURANT RESERVOIR
UPPER MUSSEL SHELL PROJECT
WHEATLAND & MEAGHER COUNTIES
STATE WATER CONSERVATION BOARD
HELENA, MONTANA
FEB 1955
DWA No. IC-48-05
SCALE AS SHOWN
DWG No. 8
Drawn by
Traced by

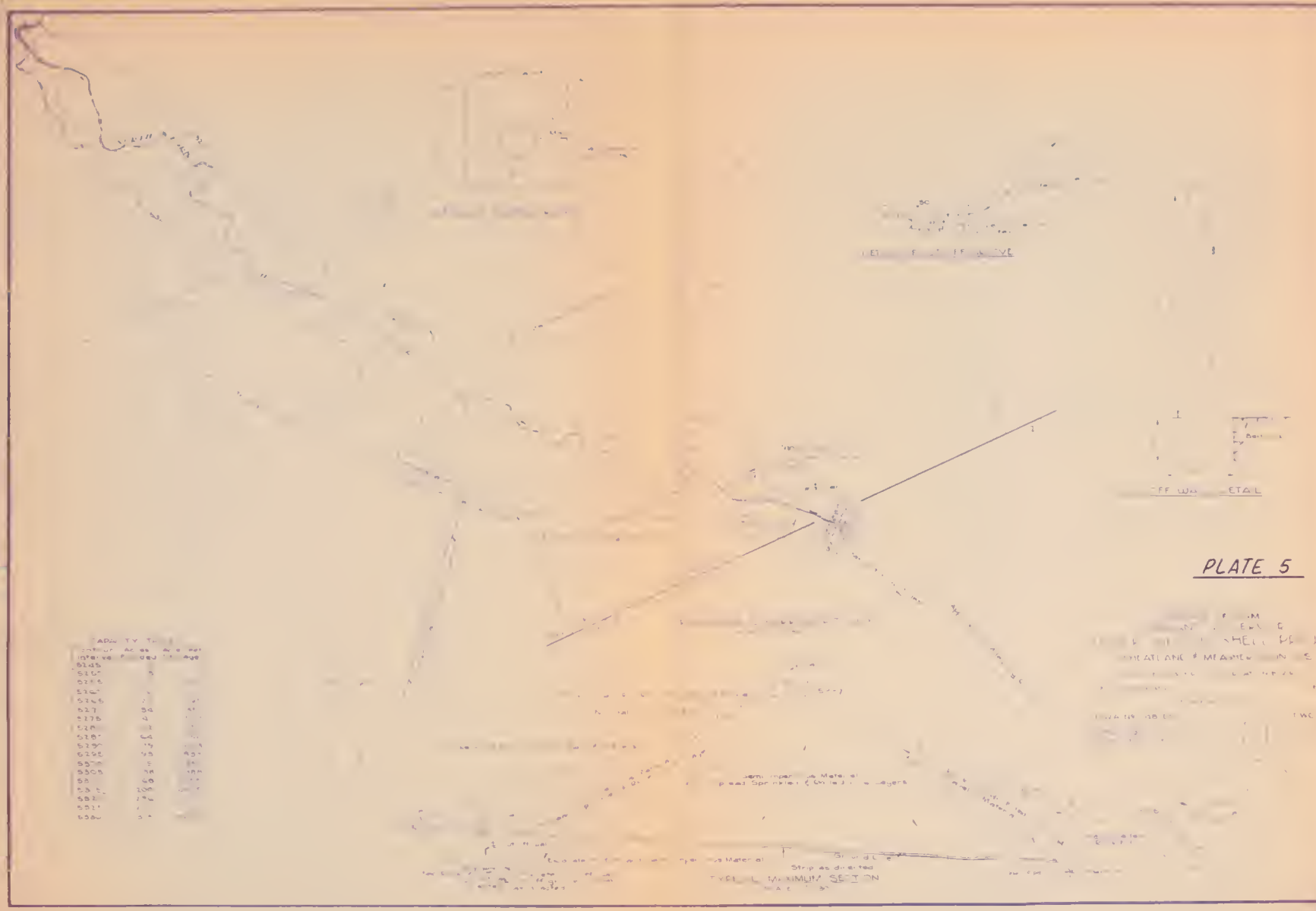


PLATE 5

RESERVOIR SURFACE AREA, ACRES

400 300 200 100 0

5340 5320 5300 5280 5260 5240

ELEVATION, FEET (NGVD)

Min. Dam Crest Elev. = 5336.4

Spillway Crest Elev.= 5325.0

Storage

Surface Area

RESERVOIR CAPACITY CURVE

0 1,000 2,000 3,000 4,000 5,000 6,000 7,000 8,000 9,000 10,000 11,000

STORAGE, ACRE FEET

PLATE 6

PMP DEPTH - DURATION CURVE

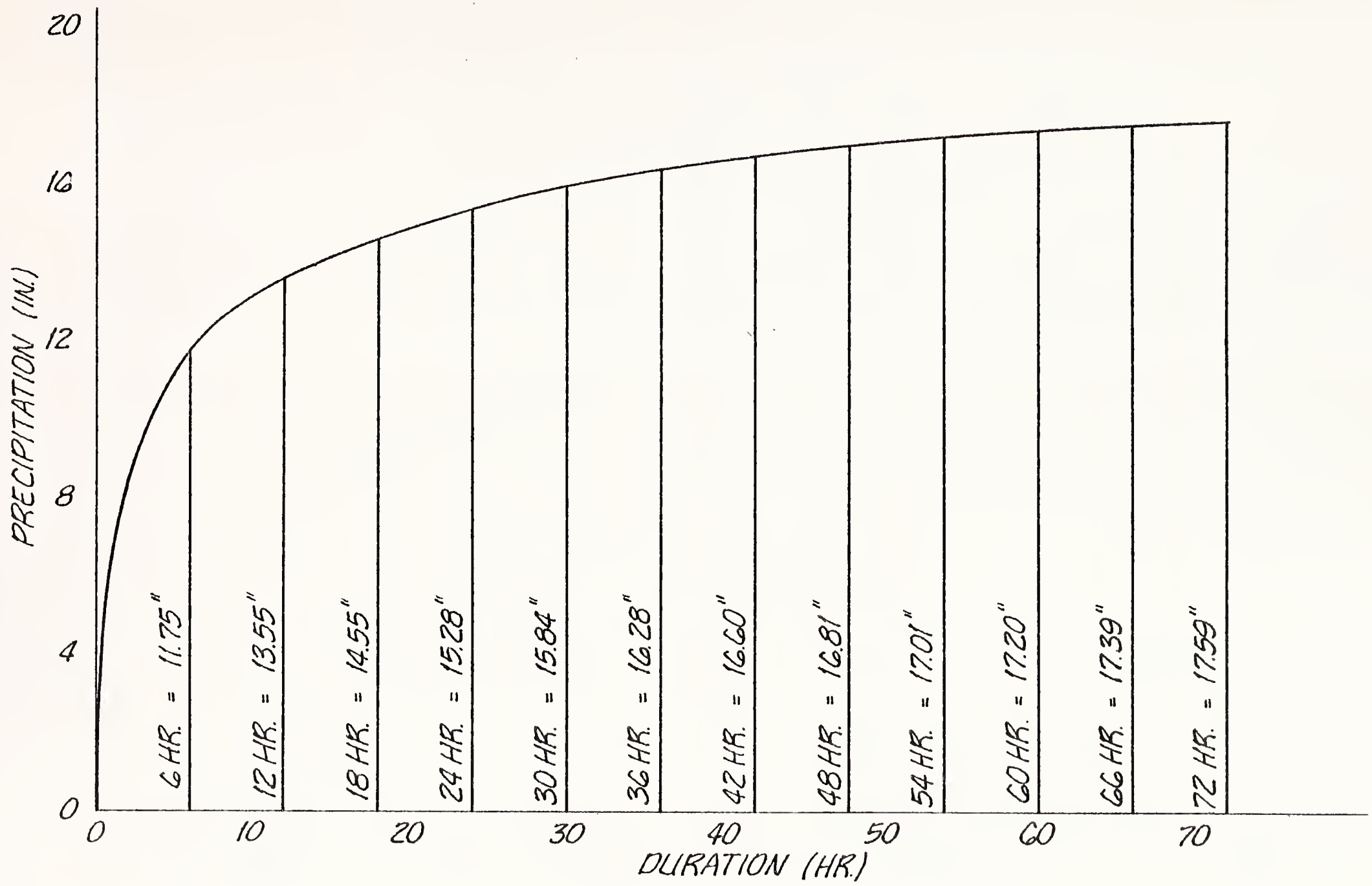


PLATE 7

54-INCH OUTLET DISCHARGE RATING CURVE

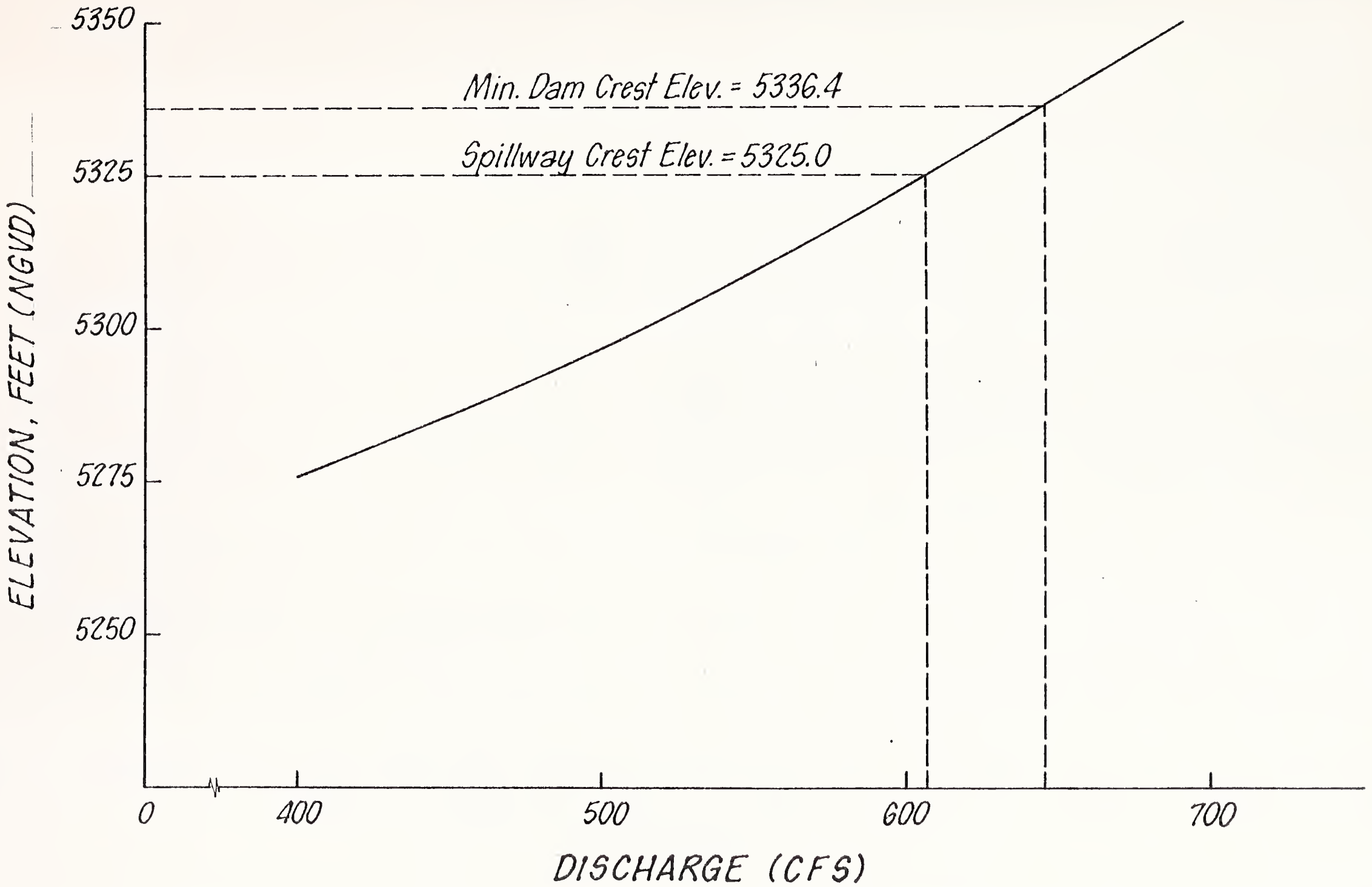


PLATE 8

SPILLWAY DISCHARGE RATING CURVE

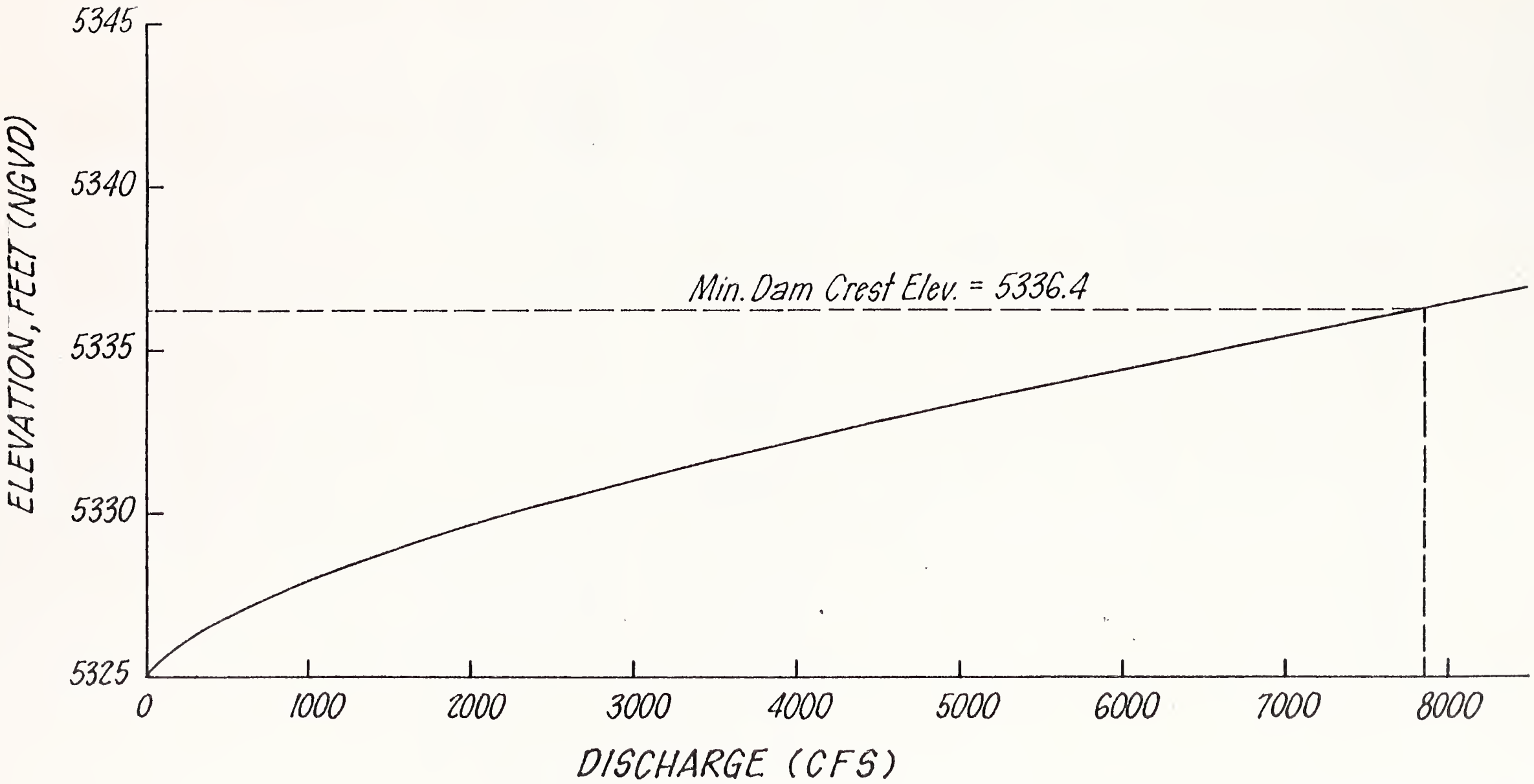


PLATE 9

DEPARTMENT OF NATURAL RESOURCES
AND CONSERVATION
WATER RESOURCES DIVISION

THOMAS L. JUDGE, GOVERNOR

32 SOUTH EWING

STATE OF MONTANA

(406) 449-2872

HELENA, MONTANA 59601

January 22, 1981

Ralph Morrison
Department of the Army
Seattle District, Corps of Engineers
P.O. Box C-3755
Seattle, Washington 98124

Dear Mr. Morrison:

The Department of Natural Resources and Conservation has reviewed the final draft report on the Bair Reservoir Dam (MT-6). We concur with the findings and recommendations in the report and feel that the report satisfies the criteria for the Phase I investigation. Our comments have been discussed with your staff and we understand that they will be incorporated into the final report.

We sent copies of the final draft report to the Upper Musselshell Water Users Association for their review and comments. Their comments are enclosed.

Thank you for the opportunity to review and comment on the final report for this project.

~~Sin~~cerely,

Richard L Bondy

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RB:LT:lj
enclosure

AN EQUAL OPPORTUNITY EMPLOYER

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MONT. DEPT. OF NATURAL
RESOURCES & CONSERVATION

Upper Musselshell Water Users Assoc.
Martinsdale, Montana 59053
December 22, 1980

Department of Natural Resources
and Conservation
32 South Ewing
Helena, MT 59601

Re: Bair Dam and Reservoir, Meagher County, Montana.

Gentlemen:

In regard to the Safety Measures, recommended by the Safety Inspection team, I would offer the following opinions on actions, practical to correct the deficiencies. I have been closely associated with this project since 1962, as an engineer for the Soil Conservation Service, in Meagher, Wheatland, Golden Valley, and Musselshell Counties until I retired in 1975. Then as Ditchrider and caretaker for the dams for 4 years, and during this time have studied quite closely, the operation and maintenance of the irrigation project.

1. Warning System - Willis Cotant, a rancher who lives about a mile below the dam and has bought dam water for irrigation, is vitally interested in the safety of the dam, would alert the proper people if any danger occurred and Civil Defense organizations would help water users where ever necessary.

2. Drain Outlet - This requires maintenance every few years it seems-Rock from the west (towards Highway) seem to keep sliding down into the outlet basin and have been cleaned out numerous times that I know of and it appears that this needs to be done before another irrigation season begins. I have thought that one solution to this, when funds are available, would be to put in a longer and higher concrete wall - to keep this material out ot the basin.

To inspect the conduit upstream from the slide gate--would seem to necessitate draining the dam as low as possible, at low stream flow--otherwise it seems impossible to follow this through.

3. If good riprap material can be found on West side of pond area--it would be easier to build haul road from that side. Then placement of riprap should start on the spillway side

and work back to the west. Number 5 recommendation could be accomplished in same way at the same time.

4. Brush has been revomed from upstream and downstream faces several times, and will continue to be a maintenance item. I doubt that any of the root holes are large enough to need filling.

5. I helped repair numerous cracks and spalled areas and those seem to be holding quite well. But others keep appearing and it seems that once every few years this will be necessary. The tops of the walls now seem to be the worst--if a roadway is built to haul riprap, it would seem that the concrete material should be moved in then--as at present, it has to be carried considerable distance by hand. Near the top of the spillway on the east side--it might be well at some time to raise the wall higher to prevent rocks, etc. from sliding down and falling into the spillway.

6. I believe that the engineering studies recommended should be done by the Department of Natural Resources. Reason for this is that there are numerous dams around the state which will be needing the same thing. The same people using the same testing equipment on the different dams should be more efficient and economical and the local orgainization is not acquainted with all things that might be invovled. Also, this project has benefitted many other people, besides the water users, such as boaters, fisherman, etc. - it seems the cost should not all have to be charged to the few people who get irrigation water from it.

7. If the studies show that the spillway has to be altered drastically, it would seem that some thought should be given to raising the dam to provide more storage.

8. I believe that inspections of this project have been made annually for quite a number of years and believe that the Directors plan to continue the same.

9. Some maintenance work is performed each year as funds are available. Some years washouts or other damage occurs on the canal part of the project and thus limits other maintenance for those years.

Marvin Witt

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